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# Which factors influence farmers' intentions to adopt nutrient management planning?

Amar Daxini [1,2,3]*, Cathal O'Donoghue[4], Mary Ryan[1], Cathal Buckley[1], Andrew P. Barnes[2], Karen Daly[5]

[1] Teagasc Rural Economy and Development Programme, Mellows Campus, Athenry, Co. Galway, Ireland.

[2] Scotland's Rural College (SRUC), King's Buildings, Edinburgh, Scotland.

[3] University of Edinburgh, School of Geo-Sciences, King's Buildings, Edinburgh, Scotland.

[4] NUIG Policy lab, National University of Ireland, Galway, Ireland.

[5] Teagasc Environment Soils and Land Use, Johnstown Castle, Wexford, Ireland.

*Corresponding Author. Email: Amar.Daxini@sruc.ac.uk. Scotland's Rural College (SRUC), West mains Road, King's Buildings, Edinburgh, EH9 3JG.

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**Key words:** Nutrient management planning, farmer decision making, farmer behaviour, adoption, intentions, theory of planned behaviour, logistic regression, principal component analysis

Abstract

The adoption of nutrient management practices can lead to win-win outcomes in terms of both improving productivity and reducing the environmental impact of farming. However, adoption of key practices remains below expectations globally. Few studies specifically focus on the adoption of nutrient management practices and the majority overlook psychological factors in their analysis. This study examines the factors which influence Irish farmers' intention to apply fertiliser on the basis of soil test results. An expanded version of the theory of planned behaviour is used as a framework for analysis. The influence of policy is also accounted for by this study which requires certain farmers in Ireland to adopt soil testing on a mandatory basis. The results for the national sample (n=1009) show that attitudes, subjective norms (social pressure), perceived behavioural control (ease/difficulty) and perceived resources are significant and positively associated with farmers' intentions. In terms of the voluntary sample (n=587), only attitude, perceived behavioural control and perceived resources are significantly and positively associated with farmers' intentions. Whereas, for the mandatory sample (n=422), subjective norms, perceived behavioural control and perceived resources are significantly and correlated in a positive direction with intentions. A number of farm and farmer characteristics are also significantly associated with intentions. Policy recommendations are made based on these results.

# 1. Introduction

The past five decades have seen a rapid increase in demand for food, owing to a persistent increase in the global population and a dietary shift towards a larger share of meat and dairy products (Lassaletta *et al.*, 2016; Swain *et al.*, 2018). To meet this demand, food production has intensified, with crop production per unit of area increasing due to increasing inputs of nutrients among other factors (Nesme *et al.,* 2018). Nutrients, such as nitrogen (N), phosphorous (P) and other micronutrients, such as magnesium, manganese and cobalt, are essential for the continued growth of global agricultural production. However, nutrients, especially N and P, also have the potential to cause environmental degradation (Lu and Tian, 2017; Lun *et al.,* 2018). Global concerns over the nutrient enrichment of both ground and surface waters and the direct emissions of nitrous oxide and ammonia into the atmosphere have led to the simultaneous regulation of nutrient use on farms in various countries (Sutton *et al.,* 2011) and the promotion of management practices that can both increase productivity and reduce environmental damage (Gebrezgabher *et al.,* 2015; Hyland *et al.,* 2018). Effective nutrient management has been advocated as one key area requiring improvement globally (Mueller *et al.,* 2012; Pasuquin *et al.,* 2014; Xu *et al.,* 2016).

Nutrient management is a process of planning for manure and fertiliser applications to individual pastures or crop fields (Oenema and Pietrzak, 2002). However, decision making surrounding this process is often influenced by the particular farm system in question (e.g. cattle, dairy, sheep or tillage) (Beegle *et al.*, 2000). For example, livestock based farming systems may have a larger emphasis on decision making surrounding manure management whereas tillage farms may have a larger emphasis on decision making surrounding the use of chemical fertiliser. However, regardless of farm system, as the ultimate goal of nutrient management is to match nutrient supply with grass or crop demand, the decision to adopt is relevant across all farm systems (Goulding *et al.,* 2008; Roberts and Johnston, 2015). However, it is important to note that whilst nutrient management is applicable to all farm systems the incentive to adopt may differ which can influence the decision to adopt. For example, intensive dairy or tillage farm systems often require larger quantities of fertiliser inputs and therefore the incentive to adopt practices that help to optimise returns from nutrients may be higher than low intensity cattle or sheep production systems (Beegle *et al.*, 2000). Soil testing is a key, though not sufficient, nutrient management practice that can be adopted to achieve the aims of nutrient management regardless of farm system (Kelly *et al.,* 2016).

Whilst soil testing remains readily available in a developed world context, adoption remains below expectations across all farm systems (Kelly *et al.*, 2016; Bruyn and Andrews, 2016). A situation has also been observed whereby farmers who do adopt soil testing often fail to fully translate these data into decision making surrounding fertiliser applications (Buckley *et al.,* 2015; Bruyn and Andrews, 2016; Kannan and Ramappa, 2017). This potentially forgoes some of the benefits that otherwise could be gained. Despite global efforts to improve uptake, there remains an international challenge in encouraging the use of soil analysis in decision making and the adoption of nutrient management practices on a wider scale (Osmond *et al.,* 2015; Collins *et al.,* 2016; Wang *et al.,* 2018). Research has shown that the lack of incorporation of soil analysis in decision making may be due to a lack of awareness, lack of perceived benefit, cost, difficulties with implementation and preference not to adopt (Brant, 2003; Osmond *et al.,* 2015; Micha *et al.*, 2018). Non-adopters may prefer to rely on, for example, personal experience, tradition and ‘informed’ intuition to influence nutrient management decisions (Nuthall and Old, 2018). However, variance in adoption and use is often found to be contingent on factors which are under the control of the farmer such as the extent of adoption and management skill (Oenema and Pietrzak, 2002; Roberts *et al.,* 2017).

Very few studies have examined the determinants of adoption of soil testing. Moreover, most of the literature focuses on the factors which influence the adoption of individual nutrient management practices (Bosch *et al.,* 1995; Caswell *et al.,* 2001; Monaghan *et al.,* 2007; Ribaudo and Johansson, 2007). Thus, less attention is given to the simultaneous adoption of a given nutrient management practice and its translation into on-farm decision making. Thus, we address a specific gap in the literature by examining farmers’ intentions to simultaneously adopt soil testing and apply fertiliser on the basis of soil test results. Furthermore, previous studies have primarily focused on examining the influence of farm and farmer socio-economic factors on adoption of nutrient management practices and, as such, the underlying psychological factors (e.g. beliefs and social pressure) which affect farmer decision making are often overlooked.

Some authors have argued that a failure to account for the influence of psychological factors on behaviour may lead to an incomplete understanding of farmers’ intentions towards such management practices (Borges *et al.,* 2014; Wilson *et al.,* 2014; Zhang *et al.,* 2016; Zeweld *et al.,* 2017). Following these authors, we extend the literature by developing a conceptual framework based on the Theory of Planned Behaviour (Ajzen, 1991) in order to advance our understanding of the factors which influence farmers’ intentions to apply fertiliser on the basis of soil test results. This will help policy makers to better target initiatives at the factors which hinder and drive the uptake of this important nutrient management practice.

This study seeks to add to the literature by examining which factors influence farmers’ intentions to apply fertiliser on the basis of soil test results, which has seldom been studied. As all farm types or systems have the potential to benefit from the use of soil testing, this study is not restricted to a particular farm system. This study uses the Republic of Ireland (henceforth Ireland) as a case study from which generalised lesson can be drawn for better targeting initiatives designed at encouraging farmers to apply fertiliser on the basis of soil test results. These recommendations are also relevant more widely as many countries face the challenge of encouraging farmers to improve their nutrient management practices.

## 2. Description of soil testing

Soil testing is a diagnostic tool which helps farmers to assess current soil fertility and pH levels of individual fields and make fertiliser application decisions based on these and expected crop yield (Adusumilli and Wang, 2017). Without analysing the nutrient status of fields, the risk of over or under applying nutrients to fields with suboptimal soil pH or fertility levels is increased (Robert, 1993). This can increase the risk of nutrient loss to the environment, lead to lower crop yields and an increase in the risk of sub optimal financial returns to the farmer (Sharpley *et al.,* 2003). The most commonly used test in Ireland is for pH and the macronutrients P and K which costs around €25 per sample. General recommendations for nutrient applications, including liming requirements, are provided in a soil analysis report by registered soil testing laboratories. It is typical for farmers to refine these recommendations based on personal experience, tradition, external advice and expected crop yields. Some of the benefits of following recommendations made by soil analysis include increased yields, improved crop quality and efficiency of input use (Robert, 1993). However, recommendations based on soil test results can incur additional costs such as the need to seek external advice and increase fertiliser and lime inputs in the short run. On the other hand, a soil test may indicate the need to reduce fertiliser application rates which the farmer may perceive as risky as application of fertiliser in excess is often viewed as a risk off-setting activity that helps to ensure high yields and economic stability (Sheriff, 2005; Stuart *et al.*, 2014). For these reasons, farmers may be averse to stringently following recommendations based on the results of soil analysis.

There are several factors which drive the adoption of soil testing in Ireland. These include water quality policy, nutrient management regulation, agri-environmental scheme entry and farm management (Shortle and Jordan, 2017). In Ireland, the adoption of periodic soil testing is mandatory for farmers who receive a derogation (allowance) to operate at a higher stocking rate, of above 170kg/N/ha$^{-1}$, under the European Union Nitrates Directive (ND) regulations (European Comission, 1991). Farmers who apply to enter and receive subsidy payments under the 'Green Low Carbon Agri-environment Scheme' (GLAS) are also required to conduct periodic soil testing (Image, 2016). However, there is evidence which suggests that farmers who adopt soil testing on a mandatory basis may not rigidly follow recommendations when making nutrient management decisions, which is not an explicit requirement as it is hard to regulate (Buckley *et al.*, 2015). Similar to other countries (Kania *et al.*, 2014), a number of initiatives are also used to encouraged farmers to voluntarily adopt soil testing and to translate the results into practice. These initiatives include knowledge transfer and exchange through, for example, agricultural education courses, national advisory services, open days, farm walks and farmer discussion groups (Prager and Thomson, 2014).

## 3. Conceptual framework

In order to examine the factors which influence farmers' intentions to apply fertiliser on the basis of soil test results, we developed a conceptual framework based on the Theory of Planned Behaviour (TPB), formulated by Ajzen (1991) to explain human behaviour. According to the TPB, intention is an appropriate predictor of actual human behaviour. Intention, in turn, depends on the beliefs held by the individual towards a particular behaviour which are based around three constructs. These include attitudes towards the behaviour, the perceived social pressure from significant others to perform the behaviour (subjective norms) and perceived behavioural control, which incorporates the perceived ability to perform the behaviour.

The TPB framework has been validated and shown to provide a structured yet flexible framework that can explain farmer decisions to adopt agricultural practices (Lalani *et al.*, 2016; Zeweld *et al.*, 2017; Rezaei *et al.*, 2018; Zeng and Cleon, 2018). The TPB is flexible because it is allows for the inclusion of additional variables if they improve the models predictive power and can be shown to be conceptually independent of the models constructs (Ajzen, 1991). As the TPB leaves a substantial percentage of variance with no explanation in intention and behaviour (López-Mosquera *et al.*, 2014; Rezaei *et al.*, 2018), we extend the model by including a number of additional variables.

Our first addition to the model is the predictor 'perceived resources'. In the context of the TPB, we follow Zeweld et al. (2017) in defining perceived resources as the degree to which a farmer perceives that he/she owns or has access to the necessary resources (e.g. finance, labour and time) and technical infrastructure (information) to support him/her in adopting nutrient management practices. Resources are an important component of nutrient management practices and, as discussed previously, adopting soil testing and applying fertiliser on the basis of soil test results can require additional resources to facilitate the process (Beegle *et al.*, 2000). Previous research has shown that resources have been found to constrain the adoption of nutrient management practices (Monaghan *et al.*, 2007) and therefore it is important to capture this variable in our model.

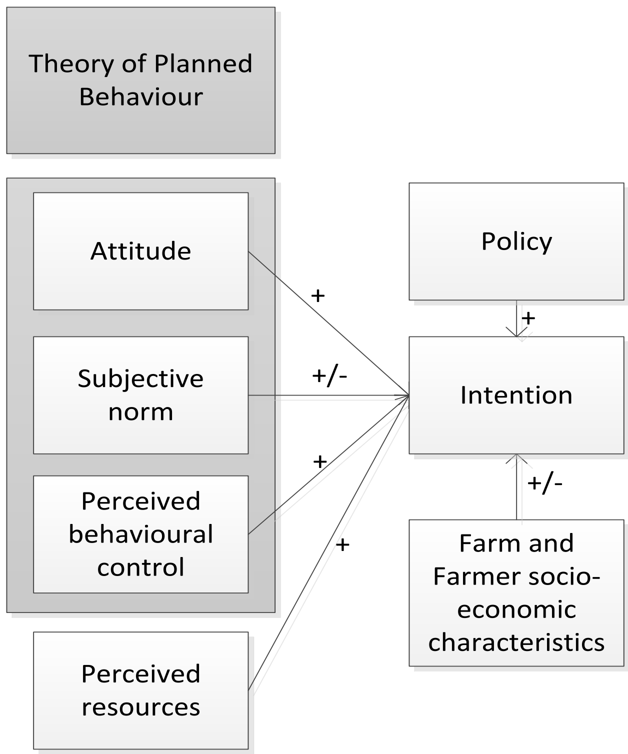
In the TPB, socioeconomic characteristics and background variables such the policy environment, are assumed to influence intention through attitude, subjective norms and perceived behavioural control. Yet, the TPB has been criticised for not accounting for such variables explicitly (Beedell and Rehman, 1999). A number of authors have addressed this limitation by explicitly including socioeconomic and background variables in their extended model of the TPB to explain farmers' intentions (Areal *et al.*, 2012; Borges and Oude Lansink, 2015; Micha *et al.*, 2015; Arunrat *et al.*, 2017). Based on previous research, discussed below, we also include a number of additional variables in our conceptual model to explain farmers' intentions to apply fertiliser on the basis of soil test results. These include farm size and system, farmer age, both formal and agricultral education, contact with an agricultral advisor and participation in a discussion group. A policy variable is also included in the analysis.

In terms of farm characteristics, farm size is frequently hypothesised to positively influence the decision to adopt due to issues associated with economies of scale. Ribaudo and Johansson (2007) found farm size to be positively and significantly associated with the probability of soil testing. Intensity of production is also generally found to be positively associated with the adoption of management practices because higher intensity farms tend to use larger quantities of inputs and therefore the scope for using practices that lead to potential cost savings, such as soil testing, is greater. Monaghan et al. (2007) showed that cost, complexity and compatibility with the current farm system to constrain the adoption of various nutrient management practices.

In relation to farmer characteristics, age is typically hypothesised to negatively influence the adoption of management practices because older farmers tend to be more risk averse. Buckley et al. (2015) found that the frequency of adoption of nutrient management practices, including soil testing, decreased with age. Higher levels of both formal and agricultural education have been found to positively increase the likelihood of adoption of nutrient management practices (Knowler and Bradshaw, 2007). Furthermore, contact with extension services such as an advisor or discussion groups have also been found to increase the likelihood of engagement of management practices. Pan (2014) found that farmers who based fertiliser application on the basis of soil test results were more likely to be in contact with agricultural extension. We incorporate these variables into our conceptual framework to explain farmers' intentions towards applying fertiliser on the basis of soil test results.

Due to the importance of policy in relation to the adoption of soil testing in Ireland (see section 2), we include an additional variable to capture the potential effect of policy on farmers' intentions to apply fertiliser on the basis of soil test results. Here we assume that farmers who have conducted soil testing to comply with policy may also have a propensity to use the results as they are available to them. Furthermore, research has found that nutrient management policy can influence farmers' attitudes towards nutrient management practices and therefore the potential drivers of intention between mandatory and voluntary adopters may also differ (Barnes *et al.*, 2009; Barnes *et al.*, 2013; Macgregor and Warren, 2006, 2015). Potential differences in drivers are also explored in our study.

**Figure 1 Conceptual framework based on the theory of planned behaviour used for the purpose of this study.**




4. Data and methodology

*Survey*

The data used in this study was derived from a structured survey of 1009 farmers across Ireland. A survey company was hired to carry out a face-to-face survey with farmers during the period January to April 2017. A quota controlled sampling procedure was set in place to ensure that the survey was nationally representative by the predominant farm system (cattle, dairy, sheep and tillage) and size (hectares) for the farming population aged 15 years and above (Hennessy & Moran, 2015). In Ireland there is no available database containing farmers' addresses that is available for research purposes. In order to obtain a nationally representative sample of farmers, the survey company initially stratified the target sample of farmers by Electoral Divisions. At each sampling point, the interviewer adhered to a quota control system based upon the known number of farm types within each area. Interviewers then proceeded to interview farmers until they filled their quotas. Quota sampling sets demographic quotas based on known population distribution statistics. The quotas used here were based on known population distribution figures in relation to specific farm types taken from the Irish Central Statistics Office (Hennessy &

Moran 2015). It was ensured that the key decision maker on the farm participated in the interview.

Quota controlled sampling is a non-probability sampling technique which ensures that specified numbers (quotas) are obtained from each specified population subgroup (Elder, 2009). A key assumption of this data collection method is that the main variability lies across, rather than within chosen subgroups, so that, once homogenous groups have been selected, it is not important which particular individuals within any groups are interviewed (Elder, 2009). Here, for example, we controlled for farm system and size and therefore other factors such as age, income and education are not controlled for. Therefore, it cannot be guaranteed that the sample is nationally representative beyond farm system and size and therefore policy recommendations should be interpreted tentatively. Despite this limitation, quota controlled sampling remains a popular data collection method due to convenience and relatively low cost and has been successfully employed in previous agricultural research (Howley, 2013; Howley *et al.,* 2015).

A review of the literature, expert consultations, farmer interviews and a pilot study were used to develop the survey. The final survey was divided into three sections. First, questions were used to collect data on farm (e.g. farm size and system) and farmer characteristics (e.g. age, education and contact with an agricultural advisor) for use as independent variables in the analysis. The second section collected information on farmers' motivations for adopting soil testing, such as regulation or participation in an agri-environment scheme, for the identification and classification of farmers as 'voluntary' or 'mandatory' adopters. The final section was based on the TPB where farmers were asked to evaluate various statements designed to reveal their beliefs and intentions towards applying fertiliser on the basis of soil test results.

*Measurement of latent variables*

In line with the conceptual framework, four types of psychological latent constructs were of relevance to this study: attitude, subjective norm, perceived behavioural control and perceived resources. Statements reflecting the constructs were developed and used in the survey to measure these latent constructs. The content and wording of the statements was based on information collected during the survey development phase. Respondents were asked to respond on a five-point likert scale, from strongly disagree (1) to strongly agree (5), the extent to which they agreed with the statements read out to them by the interviewer. Five point-likert scales have also been utilised in previous agricultural research (Gorton *et al.,* 2008; Hansson *et al.,* 2012; Adnan *et al.,* 2017). Overall, for farmer intentions to apply fertiliser on the basis of soil test results, farmers had to evaluate eight statements regarding their attitudes towards the outcomes of performing this practice, four statements regarding subjective norm (social pressure), seven statements regarding perceived behavioural control (ability) and four statements regarding perceived resources. A principal component analyses (PCA) was utilised to determine the statements underlying the latent variables with a similar structure.

PCA is a data reduction technique which operates by examining the pattern of correlations among a number of variables (Abdi and Williams, 2010). PCA transforms a group of correlated variables into a smaller number of uncorrelated variables, or principle components, that account for the most of the variation in responses (Jolliffe, 2002). Before conducting the PCA a number of common statistical tests were employed to check the suitability of the statements for PCA.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was employed. The result of the measure was 0.94 where a value above 0.5 is acceptable (KMO values range between zero and one) (Kaiser, 1974). The Bartlett's test of sphericity was also used to calculated whether the correlation matrix of the statements differs significantly from the identity matrix (Bechtold and Abdulai, 2014). The Bartlett's test should reject the hypothesis that the correlation matrix is an identity matrix. The Bartlett's test was significant at the $p = 0.0000$ level and therefore the alternative hypothesis was accepted that there is a significant relationship between the variables.

Having obtained satisfactory results from the tests, the PCA was conducted and components extracted where eigen values were greater than one (Hair *et al.,* 2010). We employed a method called component rotation which was used in order to distinguish between components and facilitate the interpretation of components (Bechtold and Abdulai, 2014). The widely applied varimax rotation was used for the purpose of this study (Abdi and Williams, 2010). Based on the eigen values we retained four components. The decision about the number of relevant statements retained on each component is guided by theory and meaning of the components (Hair *et al.*, 2010). Similar to Hansson *et al.,* (2012), we decided to retain statements that loaded onto components if they were above 0.3. This is considered as acceptable if the components make theoretical sense (Hair *et al.,* 2010). The Cronbach's Alpha was also applied to the each of four principle components in order to assess internal consistency and reliability (Nunnally, 1978). A value of 0.6 is considered as acceptable (maximum value is one) (Bechtold and Abdulai, 2014). The Cronbach's Alpha was 0.90 and 0.89 for components one and two and 0.87 and 0.69 for components three and four. The final components can be utilised as explanatory variables in a regression analysis in place of the original categorical statements.

Appendix 1 shows the results from the PCA (only statements that produced components are shown). The results are in line with the conceptual framework shown in Figure 1. The first component is attitude, which reflects personal beliefs towards the outcomes of applying fertiliser on the basis of soil test results. This component had high component loadings on statements such as "increases profits" and "increases productivity". The second component (perceived behavioural control) consisted of statements reflecting the level of ease a farmer feels that he/she can conduct the behaviour. Such statements include "I am confident in my ability to do so" and "it is under my control to do so". The third component (subjective norm) relates to farmers' perceptions of the level of social pressure to apply fertiliser on the basis of soil test results. Some examples of statements that produced this component when farmers were asked what most people think were: "think that I should" and "encourage me to do so". Finally, the fourth component comprised of statements reflecting the farmers' perceptions of resources (perceived resources). This relates to the farmers perception of whether he/she has adequate resources, such as time and finance, to adopt the practice in question.

*Explanatory variables*

In additional to the psychological variables, a number of farm and farmer characteristics are also expected to influence farmers' intentions to apply fertiliser on the basis of soil test results. The chosen variables are based on the literature discussed previously (see section three) and include farm size and system, farmer age, formal and agricultural education, contact with an agricultural advisor, participation in a discussion group and policy. The smallest category of farm size (<20ha) was selected as the reference group for analysis of the effect of farm size on intention.

This is because smaller farms generally cannot achieve the same economies of scale to engage in management practices that large farms can (Knowler and Bradshaw, 2007). In order to examine the effect of farm system on intentions, the sheep system was selected as the reference group for analysis. In Ireland, sheep farms are considered as the least intensive and generally use the least amount of fertiliser and, therefore, applying fertiliser on the basis of soil test results is not always considered a priority on such farms (Renwick, 2013). In relation to farmer age, the oldest category of farmer (65+) was selected as the reference category for analysis because older farmers tend to be more conservative when it comes to the adoption of management practices (Prokopy *et al.,* 2008). A policy variable was also developed which included farmers who participate in GLAS or receive a derogation under the ND. As discussed previously (see section two), both of these policy instruments make it compulsory for farmers to conduct periodic soil testing in Ireland.

*Data analysis*

The dependent variable for this study is farmer intention to apply fertiliser on the basis of soil test results. As the statement designed to measure this variable is based on an ordered five-point likert scale, it is typical to use an ordered regression model to analyse the data as there are more than two categories of response (Greene, 2008). However, from the full sample, only 14 farmers responded "strongly disagree" to the intention statement. Furthermore, when the sample was split into two further samples for further analysis (see below) only 13 farmers responded "strongly disagree" for the first sample and one and seven farmers responded "strongly disagree" and "disagree" respectively for the second sample. Due to insufficient responses in a number of response categories, it was not possible to decompose these categories. Therefore, similar to other studies (Läpple and Kelley, 2013; Hyland *et al.,* 2018), the responses "strongly disagree", "disagree" and "unsure" are grouped into the category "do not intend" and labelled as 0 and the responses "agree" and "strongly agree" were grouped into the category "intend" and labelled as 1. As there are now only two levels of response, the following binary logistic model is employed to explore the relationship between the hypothesized psychological and additional variables on the probability that a farmer indicates a "yes" response (positive intention) to apply fertiliser on the basis of soil test results, which can be expressed as follows:

$$In[P_i/(1-P_i\,)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} \qquad (1)$$

Where, subscript $i$ denotes the $i$-th observation in the sample, $P_i$ is the probability of the outcome, $\beta_0$ is the intercept, $\beta_1$, $\beta_2$, …, $\beta_k$ are regression coefficients of variables $X_1$, $X_2$, ..., $X_k$, respectively (Timprasert *et al.,* 2014).

As discussed previously, policy requires certain farmers in Ireland to conduct periodic soil testing and therefore it was deemed necessary to account for this influence by splitting the full sample into 'voluntary' and 'mandatory' adopters. For the purpose of the analysis farmers who participate in GLAS and/or receive a derogation under the ND were classified as 'mandatory' adopters (n=422). The remaining farmers were grouped as 'voluntary' adopters (n=587), this group also includes farmers who do not necessarily conduct soil testing currently.

In order to select the logistic regression model with the best fit, the model was run for all of the hypothesised variables in the first instance for the full sample. The results showed that farm size was an insignificant predictor of intention. Therefore, a likelihood-ratio (LR) test was performed on the full sample which compared a model which did not contain farm size to the initial model containing farm size to see if farm size significantly improved the model fit. The result of the LR test was insignificant which implies that omission of farm size does not significantly alter the model's fit. Therefore, this variable was removed from any subsequent analysis. A similar procedure was applied to other insignificant variables in the full model (formal education, agricultural education and discussion group), however the LR test was significant and therefore we chose to keep these variables in the analysis.

For ease of interpretation, the regression results are also presented as marginal effects (Table 4). The higher the marginal effect is, the higher the impact of the explanatory variable on the dependent variable is (Greene, 2008). The marginal effects for the dummy variables are estimated as the difference between the probabilities calculated at the sample mean when a dummy variable takes values of 1 and 0, respectively (Yiridoe *et al.*, 2010). Whereas for continuous variables, i.e., the PCA variables, the marginal effect is calculated at the sample mean of zero due to standardization of the PCA output (Jolliffe, 2002).

Multicollinearity between the independent variables was tested for by using the variance of inflation factor (VIF) where a VIF factor of 10 is used as a cut off value (Myers, 1990). The maximum VIF was 4.08 for the full sample, 3.37 and 5.29 for the voluntary and mandatory samples respectively. These figures suggests that multicollinearity was not an issue in our analysis.

## 5. Results and Discussion

### *Descriptive statistics*

Table 1 provides a description of the variables used in the regression models. The following descriptive statistics are for the full sample of farmers (n=1009). In line with the quotas (see section 4), Cattle farms represent 51% of the sample whereas dairy accounts for 26% followed by sheep at 17% and tillage comprising 6% of the sample. The median farm size is 31-50ha whereas the median farmer age category is 51-64. These figures are in line with national averages (Dillon *et al.*, 2017). Furthermore, 54% of farmers have at least a second level education or higher whereas around 69% have some level of agricultural education. The descriptive results further indicate that around 63% of farmers are in contact with an agricultural advisor whereas only 29% participate in a discussion group. About 42% of farmers stated that they adopt soil testing on a mandatory basis. Finally, 63% of farmers currently soil test within national recommendations (at least every 5 years) (Wall and Plunkett, 2016). This result is similar to Buckley *et al.* (2015) who found from a sample of Irish farmers that 66% were conducting periodic soil testing.

**Table 1: Variables used in the binary logistic regression analysis.**

| Explanatory variables | Description | Mean | Std. deviation |
|---|---|---|---|
| Attitude | Latent variable based on ordinal responses (5-point likert scale) | - | - |

| | | | |
|---|---|---|---|
| Subjective norm | Latent variable based on ordinal responses (5-point likert scale) | - | - |
| Perceived behavioural control | Latent variable based on ordinal responses (5-point likert scale) | - | - |
| Perceived resources | Latent variable based on ordinal responses (5-point likert scale) | - | - |
| Size[a] | Farm size (1 = <20ha, 2 = 20-30ha, 3 = 31-50 ha, 4 = 51-100ha, 5 = 101+) | 2.78 | 1.22 |
| System[b] | Main system of farming (1 = Cattle, 2 = Dairy, 3 = Sheep, 4 = Tillage) | 1.78 | 0.94 |
| Age[c] | Age of farm operator (1 = under 35, 2 = between 35 and 44, 3 = between 45 and 50, 4 = between 51 and 64, 5 = 65+) | 3.65 | 1.21 |
| Formal education | Highest level of formal education received by farm operator (1 = some secondary and above, 0 = otherwise) | 0.54 | 0.50 |
| Agricultural education | Has some level of agricultural education (1 = yes, 0 = otherwise) | 0.69 | 0.46 |
| Advisor | Farm operator is in contact with an agricultural advisor (1 = yes, 0 = otherwise) | 0.63 | 0.48 |
| Discussion group | Farm operator participates in a discussion group (1 = yes, 0 = otherwise) | 0.29 | 0.45 |
| Policy | Farm operator participates in the Irish GLAS agri-environmental scheme and/ or received a derogation in 2016 (1 = yes, 0 = otherwise) | 0.42 | 0.49 |

Notes: [a] Farm size under 20ha as reference group, [b] Sheep as reference group, [c] Age 65+ as reference group.

*Farmers' intentions*

Table 2 provides a descriptive overview of farmers' intentions to apply fertiliser on the basis of soil test result. The result is higher than actual adoption rates of soil testing alone which may be due to the use of behavioural measures which are the farmers' own perceptions of their behaviour and so are subject to acquiescence biases. This means that farmers' may provide responses to questions in a 'socially desirable' way (Beedell and Rehman, 1999; Armitage and Conner, 2001). Furthermore, farmers conducting periodic soil testing on a mandatory basis do not display a 100% level of intention to apply fertiliser on the basis of soil test results. This may suggest that farmers may adopt soil testing to comply with policy but do not intend to use the results from soil analysis to influence decision making, this concurs with the findings of Buckley *et al.* (2015).

**Table 2: Farmers' intentions towards applying fertiliser on the basis of soil test results.**

| | Intention (% of farmers) | | |
|---|---|---|---|
| Practice | National (n=1009) | Voluntary (n=587) | Mandatory (n=422) |
| Farmers' intentions to apply fertiliser on the basis of soil test results (0 = no intention, 1 = positive intention) | 79 | 70 | 92 |

*Factors influencing farmers' intentions to apply fertiliser on the basis of soil test results*

*Full sample*

Results, presented in Table 3, highlight that for the full sample intentions are influenced significantly and in a positive direction by attitude (1% level), subjective norm (10% level), perceived behavioural control (1% level), perceived resources (1% level), dairy farm system (5% level), contact with an agricultural advisor (1% level), policy (1% level) and the age groups 45 to 50 and 51 to 64 at the 1% and 10% levels respectively. This means that these groups of farmers are more likely than their older counterparts (65 and over) to have a positive intention.

All of the significant variables also have significant marginal effects. However, in addition, tillage also becomes significant at the 10% level. As the level of the psychological variables attitude, subjective norm, perceived behavioural control and perceived resources increase by one unit, the probability of a farmer applying fertiliser on the basis of soil test results increases by 2.3%, 1.6%, 3.3% and 3.2% respectively. Being classified as dairy, tillage, within the age band 45-50 or 51-64, contact with an agricultural advisor or subject to mandatory policy requirements increases the probability of uptake by 8.1%, 7.2%, 8.5%, 4.1%, 5.1% and 6.1% respectively.

The overall goodness of it of this model, as measured by $Pr > Chi^2$, is 0.0000 which implies significance at the one percent level. The $r^2$ value of the model is 0.45, which shows that the model has good explanatory power. Overall, the model correctly predicts 90.20% of the responses.

Next, the sample is divided into the two farmer groups, voluntary and mandatory adopters using the policy variable. Results show that different variables become significant across the regressions, that is, there is heterogeneity in the factors which influence intentions. A likelihood ratio-chow test is performed to test the null hypothesis that none of the model coefficients vary between the groups. The likelihood ratio-chow statistic test is significant at the three percent level and therefore we can reject the null hypothesis. This means that the two different groups should not be aggregated but instead should be examined separately.

*Voluntary sample*

Table 3 also illustrates the results for the voluntary adopters. The psychological variables, attitude, perceived behavioural control and perceived resources are each significant at 1% level and positively associated with intention, however subjective norms failed to reach significance.

Similar to the national sample, dairy system, the age group 45-50 and contact with an agricultural advisor is correlated in a positive direction with intention and significant at the 1%, 10% and 1% level respectively.

In terms of marginal effects, the variables attitude, perceived behavioural control, perceived resources increased the probability of applying fertiliser on the basis of soil test results by 5.8%, 7.0% and 5.5%. Other variables that increase the likelihood of adoption are dairy system (16.2%), age 45 to 50 (10.0%) and contact with an agricultural advisor (12.30%).

The regression model has a good fit with a $Pr > Chi^2$ of 0.0000 which implies significance at the one percent level. The $r^2$ value of the model is 0.47, which reflects adequate explanatory power. 88.42% of the sample responses are correctly predicted by the model.

*Mandatory sample*

For the mandatory sample (Table 3), attitude is not significant whereas subjective norm, perceived behavioural control and perceived resources are significant at the 10%, 5% and 5% level respectively. The variables pertaining to farmer age (age under 35, 35 to 44, 45 to 50 and 51 to 64) are all positively associated with intentions at the 1%, 10%, 1% and 5% levels respectively. Finally, the parameter for agricultural education is significant at the 10% level, with a positive effect on intention.

The estimated marginal effects suggest that subjective norm, perceived behavioural control and perceived resources increase the likelihood of a farmer applying fertiliser on the basis of soil test results by 1%, 1% and 1.4% respectively. Belonging to relatively (to over 65's) younger cohorts of farmers significantly increases the probability of having a positive intention by 7.1% (45-44), 8.1% (45-50) and 5.2% (51-64).

29 observations (farmers under the age of 35) in this model perfectly predict the outcome and therefore are dropped from the analysis, which leaves a total of 393 farmers in the sample. This model is significant, as measured by $Pr > Chi^2$, at 0.0000 which implies significance at the one percent level. The $r^2$ value of the model is 0.29, which is illustrates moderate explanatory power. Furthermore, the model correctly predicts 94.31% of the sample responses.

**Table 3: Results of the binary logistic regression for the prediction of farmer intention to apply fertiliser on the basis of soil test results (coefficients).**

| | National sample | | Voluntary sample | | Mandatory sample | |
|---|---|---|---|---|---|---|
| Explanatory variables | Coeff | Std.err | Coeff | Std.err | Coeff | Std.err |
| *TPB* | | | | | | |
| Attitude | 0.29*** | 0.06 | 0.40*** | 0.08 | 0.17 | 0.10 |
| Subjective norm | 0.20** | 0.09 | 0.16 | 0.10 | 0.31* | 0.18 |
| Perceived behavioural control | 0.42*** | 0.08 | 0.49*** | 0.11 | 0.27** | 0.14 |
| *Additional TPB style variable* | | | | | | |
| Perceived resources | 0.41*** | 0.10 | 0.38*** | 0.12 | 0.45** | 0.20 |
| *Farm and farmer characteristics* | | | | | | |
| Cattle system[a] | 0.46* | 0.27 | 0.42 | 0.34 | 0.85* | 0.51 |
| Dairy system | 0.96*** | 0.35 | 1.09*** | 0.41 | 0.49 | 0.63 |
| Tillage system | 0.81 | 0.50 | 0.83 | 0.58 | 1.05 | 0.98 |
| Age < 35[8] | 0.43 | 0.51 | -0.29 | 0.58 | -[d] | - |
| Age 35-44 | 0.04 | 0.36 | -0.41 | 0.42 | 1.62* | 0.97 |
| Age 45-50 | 1.27*** | 0.41 | 0.84* | 0.48 | 2.41*** | 0.88 |
| Age 51-64 | 0.46* | 0.25 | 0.27 | 0.31 | 0.92** | 0.44 |
| Formal education | 0.22 | 0.25 | 0.39 | 0.31 | -0.15 | 0.50 |
| Agricultural education | 0.18 | 0.23 | -0.10 | 0.29 | 0.75* | 0.42 |
| Agricultural advisor | 0.64*** | 0.23 | 0.85*** | 0.28 | 0.05 | 0.43 |
| Discussion group | 0.24 | 0.31 | 0.34 | 0.44 | 0.29 | 0.53 |
| Policy[c] | 0.78*** | 0.26 | - | - | - | - |
| Pseudo R2 | 0.45 | | 0.47 | | 0.29 | |
| Prob > chi2 | 0.0000 | | 0.0000 | | 0.0001 | |
| % Correctly classified | 90.20 | | 88.42 | | 94.31 | |
| Number of observations | 1009 | | 587 | | 393 | |

***Notes:*** Significance levels *** p<0.01, ** p<0.05, * p<0.1, [a]reference group for farm system is sheep system, [b] reference group for age is group 65+, [c]Includes farmers who have a ND derogation and farmers participating in the GLAS agri-environmental scheme. This variable is also used to split the sample hence it is absent in the voluntary and mandatory samples, [d] perfectly predicted outcome.

**Table 4: Results of the binary logistic regression for the prediction of farmer intention to apply fertiliser on the basis of soil test results (marginal effects).**

| | National sample (n=1009) | | Voluntary sample (n=587) | | Mandatory sample (n=393) | |
|---|---|---|---|---|---|---|
| Explanatory variables | Marginal effects | Std.err | Marginal effects | Std.err | Marginal effects | Std.err |
| *TPB* | | | | | | |
| Attitude | 0.0230*** | 0.0047 | 0.0577*** | 0.0112 | 0.0050 | 0.0035 |
| Subjective norm | 0.0158** | 0.0070 | 0.0226 | 0.0146 | 0.0093* | 0.0019 |
| Perceived behavioural control | 0.0326*** | 0.0061 | 0.0704*** | 0.0138 | 0.0082* | 0.0020 |
| *Additional TPB style variable* | | | | | | |
| Perceived resources | 0.0324*** | 0.0082 | 0.0554*** | 0.0180 | 0.0135*** | 0.0047 |
| *Farm and farmer characteristics* | | | | | | |
| Cattle system[a] | 0.0468 | 0.0296 | 0.0762 | 0.0639 | 0.0316 | 0.0208 |
| Dairy system | 0.0805*** | 0.0309 | 0.1617** | 0.0637 | 0.0211 | 0.0273 |
| Tillage system | 0.0717* | 0.0387 | 0.1336 | 0.0829 | 0.0359 | 0.0283 |
| Age < 35[b] | 0.0390 | 0.0427 | -0.0494 | 0.1049 | -[d] | - |
| Age 35-44 | 0.0041 | 0.0375 | -0.0724 | 0.0774 | 0.0707* | 0.0405 |
| Age 45-50 | 0.0848*** | 0.0265 | 0.1003* | 0.0517 | 0.0811** | 0.0338 |
| Age 51-64 | 0.0413* | 0.0242 | 0.0394 | 0.0447 | 0.0519* | 0.0311 |
| Formal education | 0.0173 | 0.0196 | 0.0565 | 0.0447 | -0.0045 | 0.0153 |
| Agricultural education | 0.0138 | 0.0188 | -0.0147 | 0.0415 | 0.0225 | 0.0151 |
| Agricultural advisor | 0.0506*** | 0.0181 | 0.1230*** | 0.0400 | 0.0014 | 0.0128 |
| Discussion group | 0.0187 | 0.0241 | 0.0496 | 0.0624 | 0.0089 | 0.0163 |
| Policy[c] | 0.0609*** | 0.0203 | - | - | - | - |

***Notes:*** Significance levels *** p<0.01, ** p<0.05, * p<0.1, [a]reference group for farm system is sheep system, [b] reference group for age is group 65+, [c]Includes farmers who have a ND derogation and farmers participating in the GLAS agri-environmental scheme. This variable is also used to split the sample hence it is absent in the voluntary and mandatory samples, [d] perfectly predicted outcome.

# 6. Discussion

This study uses a modified TPB approach to understand which factors influence farmers' intentions to apply fertiliser on the basis of soil test results. The significance of the policy variable in the regression analysis for the national sample provides further evidence to suggest that policy is an important driver of intention. To this end, this section focuses on discussing the significant results for the voluntary and mandatory groups only.

The first TPB variable, attitude, has a positive and relatively large influence on farmers' intentions to apply fertiliser on the basis of soil test results for the voluntary sample, however this effect is not noted for the mandatory sample. This means that farmers unaffected by policy are more likely to adopt the practice if they evaluate the outcomes of performing the behaviour more favourably than their counterparts. A possible explanation for this result is that certain groups of farmers who voluntarily intend to engage with the practice are more aware of the benefits that can be gained from doing so than other farmers within this group (Senger *et al.*, 2017). This result is in line with previous TPB studies which found attitude to be a significant predictor of intention to adopt voluntary agricultural practices (Wauters *et al.*, 2010; Rezaei *et al.*, 2018; Zeng and Cleon, 2018).

It is suggested that social norms influence people's intentions and behaviour because people do not conduct decisions independently from social and cultural influences and, instead, they are constantly referring their behaviour back to important reference groups (Burton, 2004). However, our results only partially support this assertion as subjective norm is only found to significantly influence the intentions of farmers classified as mandatory adopters. Whilst the relative magnitude of this effect is small, the result implies that farmers within this group who feel a larger degree social pressure are more likely to translate the results of soil analysis into practice. One possible explanation for this result is that a fear of further regulation, or fear of penalties, motivates farmers to behave in a way that is perceived as 'socially desirable' and to avoid further regulation in the future (Powell *et al.*, 2012; Savage and Ribaudo, 2013; Mills *et al.*, 2018).

In theory, farmers who have a strong belief in their own capability of applying fertiliser on the basis of soil test results should be more likely to do so (Ajzen, 1991). Our results support this assertion as perceived behavioural control is found to be statistically significant and has a positive influence on farmers' intentions, for both farmers classified as voluntary and mandatory adopters. However, this effect is relatively larger for farmers categorised as voluntary adopters. Previous research has found that farmers often do not lack the motivation to adopt recommended nutrient management practices, instead they lack the suitable levels of perceived efficacy to take action (Wilson *et al.*, 2014; Zhang *et al.*, 2016; Wilson *et al.*, 2018). Recommendations made by soil analysis laboratories in Ireland are based on national average fertiliser recommendations (Wall, and Plunkett, 2016) and therefore a level of technical expertise is required to refine the recommendations to suit the particular farm situation.

The variable perceived resources significantly and positively influences both groups of farmers' intentions to apply fertiliser on the basis of soil test results. Albeit, the effect is relatively larger for farmers classified as voluntary adopters. The result implies that farmers who believe that they have the necessary resources such as time, finance and labour to apply fertiliser on the basis of soil test results are more likely to do so. Whilst this result is contrary to the finding of Zeweld et al. (2017), who did not find a significant relationship between perceived resources and farmers' intentions to adopt sustainable practices, it conforms to expectations as the practice in question can require changes in management such as applying additional fertiliser, increased frequency of application, or to fields that may be difficult to access with machinery. Such practices often require additional finance, time and labour to which a farmer may not have access and which may hinder adoption (Sheriff, 2005).

In terms of farm and farmer characteristics, the dairy system is significantly and positively associated with intention for the voluntary sample. A possible explanation for this result is that dairy farms in Ireland receive the majority of their income from the market and inputs are relatively higher compared to other systems (Dillon *et al.*, 2017). Therefore, the incentive is greater to optimise returns from nutrient inputs versus other systems through the use of soil testing (Beegle *et al.*, 2000). A key implication of this result is related the need to make practices which have both economic and environmental win-win outcomes more relevant to low intensity farms (e.g. sheep and cattle in Ireland) and perhaps emphasising longer time frames for implementation for such farms.

Younger farmers are said to be more likely to adopt management practices (Weaver, 1996; Rahelizatovo and Gillespie, 2004). The results for the regression analysis for the mandatory sample strongly support this assumption (relatively large marginal effects) and demonstrate that the younger cohorts of farmers compared to their older counterparts (65 and over) are more likely to have an intention to apply fertiliser on the basis of soil test results. This result concurs with Buckley (2012) who found certain cohorts of farmers in Ireland to be 'benefit accepters' of nutrient management practices despite having to adopt them for policy compliance purposes. One possible explanation for this result is the fact that relatively younger cohorts of farmer have a longer planning horizon and therefore are more likely to adopt practices which maintain or increase production (Knowler and Bradshaw, 2007).

The positive influence that agricultural advisors can have on the adoption of agricultural management practices has been well established (Baumgart-Getz *et al.*, 2012). In our study, the role of an agricultural advisor is positively associated with intention to apply fertiliser on the basis of soil test results for the voluntary sample. The marginal effect for this result is also relatively large. This result is consistent with Ingram (2008) who found that agricultural advisors were critical to helping farmers to improve soil management decisions. Agricultural advisors can help farmers to implement management practices by providing knowledge and technical expertise, which can help to explain our result.

## 7. Conclusion

This study sought to determine which factors influence farmers' intentions to apply fertiliser on the basis of soil test results. Most previous studies of this nature tend to focus on the adoption of individual nutrient management practices but few examine nutrient management as a process which requires both adoption and implementation of practices, as such, this study addresses a gap in the literature. Furthermore, we build on the literature further by also incorporating psychological variables into the analysis which have seldom been explored in relation to nutrient management practice adoption. Overall, the results demonstrate that both psychological and farm/farmer characteristics as well as policy are important drivers of intention.

Based on the results, we suggest a number of policy implications. Efforts should be made to encourage farmers to further engage with technical support and to possibly increase levels of support during implementation. This may help to increase the levels of control that farmers feel over applying fertiliser on the basis of soil test results (Blackstock *et al.,* 2010). Perceptions of resources were important to farmers and therefore initiatives must also further acknowledge the diversity of resources farmers have available to them to incorporate soil testing into decision making. In terms of specifically encouraging farmers to apply fertiliser on the basis of soil test results who do not have to adopt periodic soil testing on a mandatory basis, an emphasis on highlighting the benefits of adopting this practice should be made in order to reinforce positive attitudes. On the other hand, in order to encourage farmers operating under mandatory policy requirements, efforts should be directed at increasing the level of social pressure for farmers to incorporate the result of soil analysis into decision making. This can be achieved by further encouraging or incentivising farmers to join group learning environments which can include farmer led knowledge exchange platforms which have a specific focus on this practice (Blackstock *et al.,* 2010). Finally, encouraging younger farmers operating under mandatory requirements to participate in decision making related to nutrient management may help to increase the use of soil test results.

In terms of limitations, this study examines intentions rather than actual adoption levels. Nevertheless, previous studies have shown that intentions have a strong direct effect on future behaviour (Bamberg, 2003). A future study could examine whether farmers actually acted on their intentions. Secondly, the study relies on self-reported behaviour which tends to result in respondents answering questions in a 'socially desirable' way (Floress *et al.,* 2018). Despite these limitations, this study provides fresh insights into identifying what determines the decision making-behaviour of farmers and possible ways of further encouraging farmers to apply fertiliser on the basis of soil test results.

Appendix 1

**PCA result for farmers' intentions to apply fertiliser on the basis of soil test results.**

| | Component 1 | Component 2 | Component 3 | Component 4 |
|---|---|---|---|---|
| Statement | Attitude | Perceived behavioural control | Subjective norm | Perceived resources |
| Increases productivity | 0.38 | | | |
| Produces better quality grass/crop | 0.39 | | | |
| Increases profits | 0.35 | | | |
| Reduces input costs | 0.33 | | | |
| Saves time | 0.33 | | | |
| Helps to protect the environment | 0.33 | | | |
| Improves soil fertility | 0.33 | | | |
| Soil testing increases knowledge about your fields | 0.35 | | | |
| Think that I should do so | | | 0.52 | |
| Encourage me to do so | | | 0.50 | |
| Would approve if I do so | | | 0.50 | |
| Most farmers I am aware of base fertiliser application on recommendations from soil test results | | | 0.47 | |
| A clear understanding of how to do so | | 0.30 | | |

| | | | | |
|---|---|---|---|---|
| I am confident in my ability to do so | | 0.39 | | |
| It is under my control to do so | | 0.45 | | |
| It depends entirely on me and not on factors enabling or preventing me from doing so | | 0.43 | | |
| It is easy to do so | | 0.33 | | |
| Is expensive | | | | -0.51 |
| Enough time to do so | | | | 0.37 |
| Access to enough labour to do so | | | | 0.38 |
| Enough financial resources to do so | | | | 0.51 |
| ***Eigen value*** | 10.21 | 2.01 | 1.73 | 1.20 |

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